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Re-thinking UK transport emissions – getting to the 2050 targets

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Transport is a complex system, integral to national and international structure and without which society cannot function. At the same time, transport is a significant contributor to global greenhouse gas emissions. In the UK a step change is required in the transport sector to achieve the legally binding reduction targets of the Climate Change Act 2008. Following the UK government's 2013 review of carbon dioxide emissions from infrastructure, this paper looks at the country's present and projected transport emissions in the context of the transport status quo and plans for growth. It argues there is an urgent need to rebalance the transport modal mix, with all modes integrated into a seamless transport system with smart interfacing between them. Drivers for behavioural change are also essential.

1. Introduction

In 2013 the UK government's Green Construction Board published a report called *Infrastructure Carbon Review* (GCB, 2013). It was a seminal point in the construction industry's initiative to lowering the greenhouse gas emissions (measured in carbon dioxide equivalent emissions) of UK infrastructure.

The report had the ambitious aim to inform, motivate and enthuse the industry in actively seeking low carbon dioxide solutions, through policy, design and commitments. This paper reviews the report's numbers and examines their significance for UK transport infrastructure and the way forward. It aims to suggest the changes that will enable the strategic move to a low carbon dioxide transport in the UK.

Transport is defined by the Oxford Dictionary as, 'a system for carrying people or goods from one place to another'. It is a critical component of economic development, globally and nationally. Transport availability and efficiency affect development patterns and can be a boost or a barrier to economic growth within individual nations (Krugman, 2009) and more widely. In the context of infrastructure, mobility can be seen as a utility, with decisions to be made on the optimum modal mix and coordination.

By creating links between disparate locations, transport encourages trade, growth and well-being. It provides access to a wider market, adding to economies of scale in production, specialisation, distribution and consumption. It is essential for geographical and social inclusion, spreading prosperity and encouraging development.

By promoting opportunities, transport allows a region to retain its young people who otherwise might move to a big city, draining the countryside of its vitality. Thus the examination of costs and benefits of transport is a complex subject, with many parameters other than just greenhouse gas emissions affecting the wisest choice for a nation (ICE, 2011).

If the underlying vision of government is for continuing national prosperity and growth, it has to ensure that the national and international transport system is fit for purpose, providing connectivity that is efficient, socially enhancing and environmentally positive.

2. National emissions and transport now

The UK has 'offshored' much of its manufacturing, which has provided apparent territorial emission reductions, although less control of consumptive emissions, with manufacturing powered by grids elsewhere and contributing to the territorial emissions of others. The *Infrastructure Carbon Review* provided the latest inventory of carbon dioxide equivalent emissions in the UK, estimating total national emissions to be 981 $MtCO_{2e}$ a year on a consumptive basis, including imported emissions that were previously unaccounted for in the strictly territorial assessments.

More than half of the total UK emissions are due to national infrastructure, of which transport is a significant 159 $MtCO_{2e}$ per annum, accounting for 16% of the total. The majority of transport emissions are from use of transport infrastructure – that is the tail-pipe emissions from cars, trains, ships and aircraft – rather than infrastructure construction and operation. In 2010, over 60% of transport emissions derived from road use, whereas rail was an extremely low 2%, as graphically displayed in Figure 1. Cars were the dominant mode, emitting 52% of the total transport sector, with road freight third, responsible for 11% (Figure 2).

2.1 International transport

International aviation has grown over the last 40 years at an annual rate of 5% (DfT, 2013). Shipping is a dominant force and globalisation of trade has led to significant increases in shipped volumes. Accounting for emissions from international aviation and shipping is problematic due to differing accounting methodologies. The allocation of consumptive emissions enters into the realms of higher-level, international agreements. As a consequence, international aviation and shipping have not yet been included in the UK's Climate Change Act 2008 (2008), despite the recommendations of the Committee on Climate Change (CCC) for their inclusion.

The *Infrastructure Carbon Review* recognised the need to move from a territorial methodology to a consumption-based methodology and attempted to reconcile the two by considering international aviation and shipping on the basis of departing journeys. Therefore, emissions from flights and ships that depart from the UK are counted, but those that arrive are not. Thus, international aviation and shipping emissions account for 20% and 6% of total UK transport emissions, respectively (Figure 3).

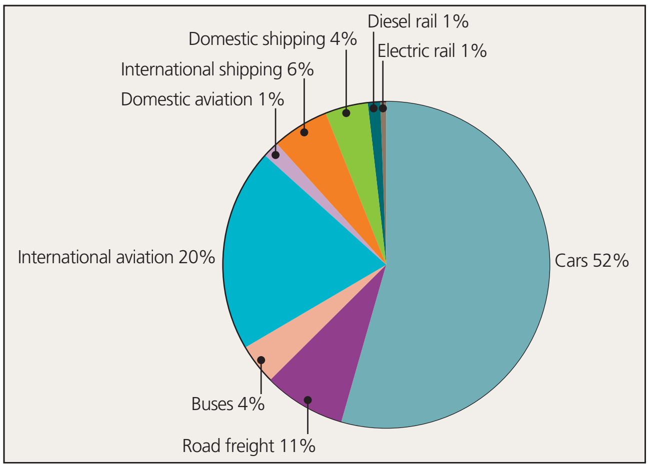

Figure 1. UK transport emissions by mode (GCB, 2013)

Figure 2. Cars and trucks account for 63% of UK transport emissions

Figure 3. International aviation accounts for 20% of UK transport emissions – but only flights leaving the country are counted

2.2 Energy waste in transport

Understanding the efficiency of a national transport system requires an understanding of how much energy different transport modes waste and hence how much carbon dioxide they waste. MacKay (2008) presented the efficiency of different passenger transport modes in terms of energy consumption per passenger kilometre travelled and speed of travel – reproduced in Figure 4.

For example, walking and cycling are extremely energy-efficient means of transport, but transport a single passenger over small distances at low speeds. On the other hand, a private car is high on wasted energy for transportation of a small number of passengers, with more luxurious cars even higher.

Per passenger-km travelled, public transport emits less carbon dioxide than a car at average occupancy (Hodges, 2010; Richardson *et al*., 2008). Shifting away from private towards mass modes of transport will result in reducing wasted energy per passenger-km. However, such transformations can take time to achieve, involve large capital carbon dioxide investment – the emissions associated with construction and decommissioning – and the need to alter city fabric as well as public perception.

Figure 4 comes with some caveats that are extremely important when considering the sustainability of mass-transit systems, requiring a holistic understanding of each transport mode and its sensitivity. Ridership and urban form will have a major impact on the capital carbon and cost of rail (Saxe *et al*., 2015).

Buses and trains are particularly sensitive to ridership: a bus may have lower operational carbon dioxide – emissions associated with operation and maintenance – when full, but this advantage degrades as ridership decreases. A transport network supported by real-time information that can elastically respond to match supply and demand can bring about large efficiency savings together with reduced wasted energy.

The same information network can provide simple knowledge on likely waiting times to potential mobility consumers, which also encourages public transport use over the convenience of immediately available private transport. In time, with autonomous vehicles, there will be a blurring of the strict distinction between public and private transport.

2.3 Freight transport

MacKay (2008) also produced a similar plot comparing different freight transport efficiencies reproduced in Figure 5, which is very informative on the current national strategy of distribution and delivery of goods and resources and its emissions footprint. Road freight, which is the currently dominant form of land transport, is ten times less efficient in transporting the same load of goods over the distance compared to rail freight.

Freight transportation is arguably a bigger generator of emissions and is frequently competing with passenger transportation for capacity on the same roads and railways. Thus a solution for one type of journey should be cognisant of its effects on others, and the big picture is most important in terms of strategic decision making on future expansion of transport and consideration of other technologies in the mix that, to date, have not been seriously considered in the UK (e.g. road freight trains).

2.4 Transport and the city

Urban transport emissions are a significant part of the national total. Urban transport is a super-complex system with socio-economic, political and geographical implications. London accounts for about 13% of the total UK population and its 9·4 $MtCO_{2e}$ transport emissions (TfL, 2011) are almost 10% of the national total ground-based transport emissions.

The density of a city dictates the energy efficiency of its transport. Barcelona and Atlanta have populations of about 5 million people, but Barcelona's dense nature and plentiful public transport allows its citizens to expend just a tenth of the carbon dioxide emissions on transport that sprawling Atlanta requires (NCE, 2014).

Jahanshahi and Jin (2015) suggest that there are three types of population density across the UK when considering the passenger transport distribution. They say 20% of the population lives in dense areas with access to good public transport and so can take advantage of it, while 30% live in low-density rural areas where

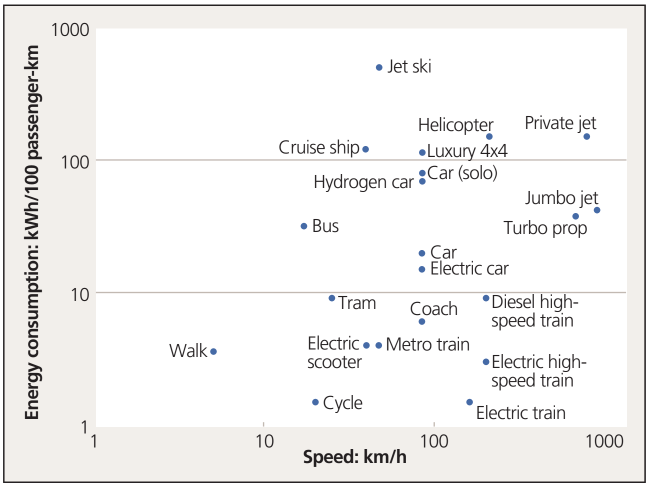

Figure 4. Energy efficiency of passenger transport modes plotted against speed – note all vehicles are full apart from 'car (solo)' (reproduced from MacKay (2008))

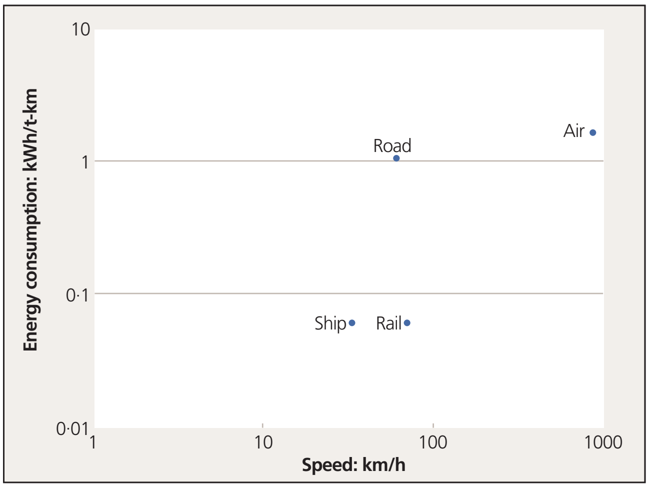

Figure 5. Energy efficiency of freight transport modes plotted against speed (reproduced from MacKay (2008))

private car journeys are probably the only option. It is in the suburban areas of intermediate density, where the remaining half of the UK population lives, where there is an opportunity for significant mode shift to less wasteful modes of transport.

2.5 Policy and perceptions

Recent policy decisions that aimed to reduce transport emissions have had mixed results. The claimed efficiency benefits of diesel have proven to be a double error. First, although lower carbon dioxide emissions are achieved, large amounts of particulate matter have a much greater and more damaging effect on human health in the short term. Second, the improved efficiency has been offset by an increase in travel distances by journeys.

In the recent past, private car ownership had become a status symbol with the run-down of public transport up to the 1980s. The famous apocryphal quote from the Thatcher government era, ‘A man who, beyond the age of 26, finds himself on a bus can count himself as a failure’, best describes the mentality where private cars were prized possessions, irrespective of the practicalities or efficiencies as means of transport.

Public perception is now maturing, with the realities of ever-increasing traffic congestion and cost of owning and running a private car leading to a public understanding of the advantages of mass-transport alternatives.

Furthermore, the nature of private transport is evolving: in congested urban areas like London, walking and cycling are becoming a preferred alternative to short car trips. Recent statistics (TfL, 2012) indicate that one-third of the 4·6 million daily car trips in London are less than 2 km. Based on a very rough calculation, this is equivalent to at least 135 000 t of carbon dioxide per year in heavily congested urban traffic. Two kilometres can be easily covered on foot or by bicycle (Figure 6).

A modal shift from short car journeys would therefore directly eliminate 135 000 t of tail-pipe emissions (1·5% of the total London transport emissions) and, more importantly, relieve the higher stop–start emissions associated with traffic congestion.

Figure 6. In London, which accounts for 10% of UK ground-based transport emissions, one-third of car trips are under 2 km – an easy walk or cycle

Alignment of growth with emissions targets must be realised across all infrastructure sectors, recognising the exceptionally long time for solutions to be implemented

3. Transport in the future

Large infrastructure schemes have long gestation periods. The Crossrail cross-London railway was first mooted in the 1940s. Hard planning for the current scheme started in 2001, with parliamentary approval in 2008 and full opening expected in 2019. This represents 18 years of continuous work – 7 years of design and planning, some 2 years of enabling works, then about 9 years of main construction.

Likewise, work on the High Speed Two (HS2) north–south national rail route started work in 2009 with a view to phase 1 opening in 2026, a period of at least 17 years. Thus transformational infrastructure projects take about a generation from firm commitment to actual operation.

The *Infrastructure Carbon Review* made use of projections from 2010 to 2025 and through to 2050 (Figure 7). These are based on the Department for Energy and Climate Change’s pathways to 2050 model (DECC, 2013), using the Markal 3.26 scenario. They considered a wide range of sources including governmental and international reports up to the year 2006, but not beyond that. These projections are not currently aligned with national business and growth aspirations and strategies, as described below.

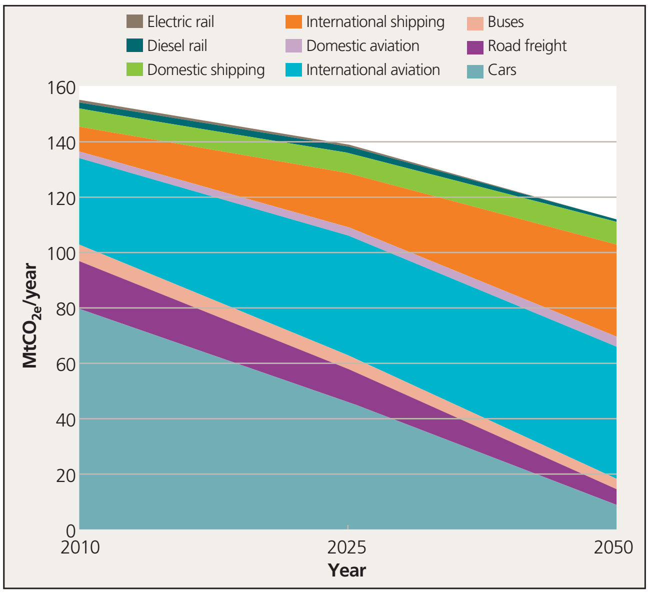

Figure 7. Current and projected greenhouse gas emissions from UK transport modes

Alignment of growth with emissions targets must be realised across all infrastructure sectors and reflected in the UK Treasury's infrastructure pipeline – recognising the exceptionally long time for solutions to be implemented.

3.1 National transport

As 2025 approaches, road car emissions are projected to drop dramatically to 33% of transport emissions and international aviation is projected to approach parity with cars.

The projections suggest that rail starts from a very low emissions contribution in 2010, which further reduces by 80% by 2050, predominantly a result of increased electrification using a lower carbon dioxide electricity supply. This is likely to include projects such as the northern hub and Great Western electrification schemes, as well as HS2, HS3 and maybe others. Considering the increased demand due to mode shift plus the electrification of traditional diesel lines, these savings are significant. However, to date Network Rail has assessed that only 60% of its lines offer a good cost–benefit ratio for electrification (Casey, 2014: p. 21).

Of all transport modes, road has the greatest projected emissions savings, with an overall 82% reduction between 2010 and 2050, presumably due to electrification of vehicles and network upgrades. A long-term lower carbon dioxide solution for freight vehicles is yet to be found, so the forecast long-term road freight emissions reduction can only be achieved by strategically shifting freight onto rail or possibly domestic shipping. Road journey times are highly variable and so moving on to infrastructure with less journey time variability will carry low economic risk and likely hold positive economic benefits.

Domestic aviation, although initially small, is projected to increase emissions by 60% by 2050. This is at odds with the general trend of phasing out short-haul flights and a shift towards high-speed rail.

3.2 International transport

The growth in international aviation and shipping is predicted to continue, although at a slower rate. This growth is reflected in an increase of 51% in aviation emissions and a massive 173% in shipping emissions by 2050. Much of this growth will wipe out the hard-earned savings in the road sector and others.

Aviation's energy requirements make it unsuited for a lower carbon dioxide electricity supply. The power–weight ratio of battery technology is unlikely to offer a viable technical solution for air travel before 2050. However, flights remain the most efficient means of transport per passenger-km over long distance and long-haul passenger travel will continue to be dominated by aviation, although the rate of growth could reduce. Measures such as reducing aircraft fuel consumption on the ground and through glide paths may moderate aviation emission impacts until technology catches up.

Shipping is more amenable to technological improvements for increased efficiency. Improvements such as improved hull design, engine and propulsion design can offer 20–30% savings (ABS, 2013) (Figure 8). Research has identified the use of small nuclear reactor systems to power bulk carriers as a means of providing sufficient propulsion at a reduced carbon dioxide output, yet significant investment challenges and regulatory uncertainty pose real barriers (Dedes *et al.*, 2011).

Figure 8. Unlike aviation, shipping can be readily made more energy efficient – with small nuclear reactors a possibility

3.3 Subsidies

The role of fossil fuel subsidies on transport modal choice should also be considered. A recent International Monetary Fund working paper (Coady *et al.*, 2015) has put remarkable figures to the scale of the subsidies, at around US$4·9 trillion in 2013 and rising to US$5·3 trillion in 2015. The implications for this on the cost–benefit analysis of transport infrastructure planning are profound and the value of traditionally held modes is set to change following the UN Climate Change Conference in Paris 2015.

4. Strategic transport

Technological advancement is often considered the primary means for resolving the emissions problem. However, the impact of new technologies at the macro scale is difficult to quantify and hence effective policy is difficult to implement. Almost independent from technological changes, a successful long-term national strategy is needed to ensure that transport remains true to its definition and operates as a seamless system transporting people and goods, rather than the sum of different transport modes competing against one another.

If roads and rail are strategically considered as an integral part of a national connectivity system, then transport efficiency can be optimised. This is not currently the case in the UK. The bulk of freight is transported on roads, while rail freight competes with and is constrained by passenger transport on the limited rail routes available.

The government's recent road investment strategy (DfT, 2014) provides a long-term vision for the strategic road network and a much-needed longer-term investment plan, but still considers the network in isolation from the rest of the transport system. As an example, the strategy plans for improvements of road freight connections for the ports in the south-east, but without making the long-term economic and emissions case compared to a freight rail option.

4.1 Rebalancing the modal mix

Meaningful transport emissions reduction can only result from considered rebalancing of the modal mix, together with smart interfacing between modes that is flexible to optimise ridership and eliminate congestion.

Decarbonisation of road passenger transportation, together with upgrading road infrastructure, will play a major role in the reduction of the single biggest current polluter. This must be assisted by a shift of freight transport off the road network, as it is technologically difficult to decarbonise.

Electrification of existing rail should be considered on the basis of value–benefit ratio, including wasted energy reduction potential as well as capital cost. Increased capacity on passenger rail lines such as HS2 has the potential to free up freight capacity on the classic rail lines it bypasses and thus possibly lead to significant energy savings as a result of enabling that substantial modal shift from road freight to electrified rail freight (Figure 9).

New access provision to major distribution hubs such as ports and airports and new freight capacity should be created using least-energy-wasted means, favouring rail against road. This will reduce the disproportionately large emissions that can be associated with the 'last mile' problem.

Freight transport into urban environments should be overhauled, with goods distribution centres located outside the urban perimeter, from where goods are disseminated to urban destinations by means of light rail – possibly underground – or other coordinated and least-polluting modes.

Individual freight companies are optimising their individual journeys; significant savings could be made by strategically connecting across companies in order to increase load factors on all journeys. This would require legislative support, such as taxation on void space in lorries and incentivising of territorial transport rights and shared logistics. As freight transport is dominated by volume and not weight, there are efficiency opportunities through the use of longer and larger vehicles, especially for the trunk part of journeys.

Substantial emissions savings can also be achieved with a shift from short-haul passenger flights to high-speed rail. Airport congestion will then be eased if short-haul aviation is largely phased out, making space for the unavoidable long-haul demand and demoting the need for airport creation and expansion.

Figure 9. Rail freight is ten times more energy efficient than road freight – new high-speed rail schemes will free up freight capacity on existing lines

Energy-efficient mass-transport passenger options should be developed to and from city centres for the suburban and rural areas that are currently mainly dependent on private transport. More fundamentally, reduction of the underlying need for travel should be addressed by better integrating land use and transport planning, aiming for reduction in demand of both number as well as length of journeys.

4.2 Hard and soft interventions

A strategic optimisation of the transport system will require both hard and soft interventions. The hard interventions will involve a substantial upfront capital investment in upgrading existing and constructing new infrastructure.

The soft interventions should drive changes in the behaviour of transport users. There is a great deal of spare capacity on many sections of the network at different times that can and should be utilised as and when it is possible and appropriate. This second policy aspect will require a drive for behavioural change, resulting from a realistic mapping of human interaction with infrastructure, which should also dictate and influence the engineering interventions. The revolution in large, crowd-based data sources will enable a better understanding, providing data and insights that were previously not possible. More fundamentally, it will also require behavioural change of the users that will drive the modal shift for increased efficiency.

5. Conclusions

The UK Climate Change Act 2008 (2008) was the beginning of the regulatory push to a lower carbon dioxide emissions economy to avoid dangerous climate change. The legislation requires an overarching reduction of 80% in emissions by 2050 compared to 1990 levels, but does not stipulate how or where these savings will come from.

As time has progressed, it has become imperative to identify strategically the sectors that will be required to make savings and plan how those savings will be made. Emissions reduction must take centre stage in the Treasury's assessments of infrastructure investment in the UK, in line with the traditional economic metrics.

It is now less than 10 years from the fast-approaching 2025 and its interim targets. The encouraging trends observed in 2013 seem to have reversed (GCB, 2015), suggesting that some of them were due to the recent recession. The rate of change must accelerate to achieve the tangible results required. It is of great importance that progress to date and the implications of this for progress into the future are assessed.

The 2013 *Infrastructure Carbon Review* was an important step in recognising how the significant infrastructure sector will contribute to reaching the 2050 target; given its systemic nature, the types of changes will be different to those proposed and implemented to make buildings more 'carbon efficient'.

This paper has attempted to put the transport section of the report into context and prime the necessary discussions for the strategic decisions to be made. Strategic decisions on emissions must be made, which will involve major capital investment. Incremental improvements in transport efficiencies are not enough; considering the entire transport system as a whole and making strategic decisions is paramount. Modal shift is of fundamental importance that cannot be achieved on the scale required if each mode within the transport sector acts without strategic direction.

The control and optimisation of emissions will require the following.

- Standardisation of the boundaries of life-cycle assessments (as discussed by Saxe *et al.* (2015) for rail) – this is now possible following the recent publication of PAS 2080 (BSI, 2016).
- A coherent national strategic plan or 'roadmap' for transport for the next 35 years to 2050, setting out the main transformational projects that will be required and identifying a bespoke funding mechanism, recognising that each large transport project will take over half of that period to bring to fruition.
- Within that transport roadmap, prioritisation of infrastructure projects that will bring the largest whole-life emissions improvements in the national infrastructure system.
- Enabling behavioural change on passenger transport choices through a mix of smart infrastructure provision and regulation.

This paper is not simply about the optimisation of the current transport paradigm. Rather, it is about a fundamental change to the modal mix and a transformation of the national transport system to serve national prosperity best while enabling the substantial greenhouse gas emissions reductions required.

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